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ABSTRACT

The purpose of this practicum was to determine if adult students engaged in training for high technology jobs can realize a time savings if customary or metric units of measure are used for practical mathematical calculations. Two quizzes were developed, and validated, using customary and metric units for the same type of problem, and the time to solve each problem was recorded. The objective was to determine if there was a significant difference in time per correct answer for either unit of measure. Both quizzes, each having both units of measure for different types of problems, were give to 20 industrial adult students without prior notification. Provided with each quiz was an instruction sheet regarding the procedures to be followed and method of recording time. The recommendation resulting from this study is that practical mathematical calculations be performed using metric units of measure to the extent permitted by limiting variables including measuring and test equipment, specifications, and blueprints which have not been converted to metric units. The paper includes an introduction to the problem, its background and significance, and procedures for the study, data resulting from the study, and conclusions. Copies of the quizzes and the statistical calculations are appended. (KR)

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TIME COMPARISON OF PRACTICAL MATHEMATICAL CALCULATIONS USING CUSTOMARY AND METRIC SYSTEMS

HISTORY, PHILOSOPHY, AND NATURE OF ADULT EDUCATION

ED325397

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by

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DALLAS II

A PRACTICUM PRESENTED TO NOVA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF EDUCATION

NOVA UNIVERSITY

SPRING 1985

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ABSTRACT

Parallel with the evolving history of adult education in the United States has been an emergence of customary or metric units of measure by occupation. Although the choice of preferred units of measure may not be a problem within an occupation, educators interfacing between occupations have been faced with the teaching of dual units of measure including numerous conversion factors. In the comprehensive "Report to Congress" by the United States Department of Commerce in 1971, it was reported that educators saw substantial benefits from the use of the metric system. However, data were not provided, nor found to be available at present, to justify statements of such benefits.

The purpose of this study, at management's request, has been to determine if adult students engaged in training for high technology jobs can realize a time savings if only customary or metric units of measure are used for practical mathematical calculations. Two quizzes were developed, and validated, using customary and metric units for the same type of problem, and the time to solve each problem was recorded. The objective was to determine if there was a significant difference in time per correct answer for either units of measure.

Both quizzes, each having both units of measure for different types of problems, were given to twenty industrial adult students without prior notification. The students had previously received instruction and been tested using both the customary and metric units of measure. Provided with each quiz was an instruction sheet regarding the procedure to be followed, method of recording time, and allowing the use of calculators.

The initial data revealed that all students made a grade of 70 or higher for both the customary and metric problems with a mean grade increase of 8.5 points, fewer problems missed, and less time used for the metric problems. Analysis of these data for time per correct answer, using a .05 level of significance for the dependent two-tailed t-test, revealed the time difference was significant. The problems using customary units of measure took a significantly longer period of time per correct answer, with 44.9 percent less time per correct answer for the metric problems.

Additional analysis revealed the lower test time and the increased number of questions answered correctly for the metric questions were also significantly different, using the same test of significance. In addition, analysis of the frequency of types of problems missed, by units of measure used, showed the need for more emphasis on certain aspects of instruction for both units of measure.

The recommendation resulting from this study is that practical mathematical calculations be performed using metric units of measure to the extent permitted by limiting factors. Such factors are measuring and test equipment, specifications, and blueprints which have not been converted to metric units.

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Chapter 1

INTRODUCTION

Concurrent with the evolving history of adult education within the United States has been a vacillation of preferred units of measure. Although legalized in 1866, the use of the metric system was not made compulsory and the Mendenhall Order of 1893 established metric units as the fundamental base of all United States customary units. As a result, a preference for units of measure began to emerge according to occupations, creating a chasm between science and practical applications (Bush, 1966:28). As education has tried to span this chasm, in support of high technology, conversions between the two measurement systems have created an additional and time-consuming task which distracts from the learning process. This additional task lacks a criterion of relevance to support achievement of problem solving for new learning situations (Howe, 1978:249). This additional task also increases in significance during cross-training and retraining of adults for new high technology jobs.

With the signing of the Metric Conversion Act of 1975 (Public Law 94-168), the use of customary and metric units of measure continue to remain voluntary with education and training teaching

both units of measure. Thus, the requirement of two measurement systems continues according to the use of units of measure preferred by subject, or occupation, and use of international data. In addition, polarization by measurement system continues with each side claiming their measurement system is equal to, or superior to, the other measurement system.

Statement of Problem

The nature of the problem for this research has been to determine if there is a significant time difference between solving practical mathematical problems by use of either customary or metric units of measure. The purpose for this effort has been to determine if industrial adult students engaged in training for high technology jobs can realize a time saving if only customary or metric units of measure are used for practical mathematical calculations. Inquiries have failed to provide data to support either position. While it may appear obvious, for example, that the use of fractions is slower, this argument could be offset by the use of calculators. The lack of data was reconfirmed by an inquiry during the Annual Conference of the United States Metric Association held in San Antonio, Texas, 19 - 20 October 1984. Conference speakers, including representatives from the Department of Commerce, Department of Education, and the Texas Education Agency, knew of no time

comparison study of solving mathematical problems by using the two measurement systems. In addition, the speakers expressed their interest in receiving a copy of such a study, if performed. Thus, this research provides data for determining if a significant time difference exists for adult students solving practical mathematical problems by using either customary or metric units of measure. In addition, this study provides a basis for an employer of industrial adult students whereby a decision can be made regarding the time effect of performing calculations in either measurement system.

The method of investigation involved both developmental and experimental methods of research. Two specially designed quizzes were given to obtain data for experimental analysis. Both quizzes were validated prior to use.

Research Hypothesis

Adult students can perform practical mathematical calculations in less time using customary units of measure rather than metric units of measure.

Chapter 2

BACKGROUND AND SIGNIFICANCE

Education has previously been enthusiastic about the simplification of teaching and the learning process provided by the metric system. In the comprehensive "Report to Congress" by the United States Department of Commerce in 1971, educators reported that they saw "substantial benefits more than compensating for the cost of a metric changeover." This report also noted that an Australian metric study arrived at an almost identical conclusion: "There seems no question that considerable time would become available for valuable new work if metric units were taught in place of the Imperial." The British Association for the Advancement of Science "estimated" in 1960 there would be a five percent savings in total school time for children between seven and eleven years of age. Similar statements cannot be found for adult students, including an evaluation of the relation of units of measure as a function of the nature and philosophy of adult education. In addition, data to support even the above existing statements are not available, and all writers are not in agreement as to the metric system having a tradeoff value. For example, the author of Megatrends states that the "high-tech of metric is being imposed on people without any high-touch tradeoffs,"

that "traditional measure is simply too well-ingrained for us to want to change," and "High-tech metric has gone as far as it is going to go" (Naisbitt, 1983:44).

Most adults tend to avoid the metric system because they have not previously thought in metric terms and have been burdened with conversion factors (Izzi, 1974:15). However, the Metric Conversion Act of 1975 has been one of the factors for adult expansion in labor education programs (Boone, 1981:210), but has been regarded as requiring very little formal training (Rau, 1975:5) if only the metric system is taught without the use of conversion factors, When an employer must train employees to convert between the two measurement systems, that portion of the training effort then becomes significant (Elwell, 1976:3). However, some types of mathematical equations require modifications to compensate for the use of certain units of measure (Joshi, 1976:11). For example, an equation for machine settings for speeds and feeds for a desired product surface finish must use modified factors to change inches per minute to millimeters per second. Such types of modifications are also applicable to existing computer applications based upon how they are programmed (ANMC, 1976:72).

The major difference between the two measurement systems is that customary units of measure are unrelated units with arbitrary conversion factors to change to a larger or smaller unit of the same

type, whereas, metric units of measure are related by a factor of ten for larger or smaller units of the same type (Keller, 1975:166). However, this apparent advantage of the metric system is not readily accepted. In the 1978 "Report to the Congress" by the General Accounting Office regarding implications of adopting the metric system, concerns by labor and industry officials were expressed regarding productivity. It was stated that a changeover could cause workers to "work more slowly and less surely and, therefore, be less productive." In a contrasting point of view, the training by business organizations and educational institutions was stated to control success. Accurate analysis of needs, knowledge of subject matter, rational thinking, and defined strategy are what determines success or failure (Martinek, 1976:8).

Given this background summary, and the lack of data, this study was performed for an industrial employer to determine which units of measurement require the least time for practical mathematical calculations as applicable to the philosophy and nature of adult education. The justification for this effort was to decide if training time could be reduced by standardizing on only one measurement system.

To ensure the significance of this study, only the number of correctly answered questions were used as a function of the total test time in order to determine significance. A problem solved

incorrectly had the same effect as requiring more time to perform the calculation. Thus the conclusion is based upon total time per correct answer.

Chapter 3

PROCEDURES

Definition of Terms

The following definitions are provided for clarification of the context in which they are used within this study.

Adult Students

Students 25 years of age or older who are employed full-time and enrolled in an industrial class providing instruction and requiring practical mathematical calculations in both customary and metric units of measure.

Customary Units of Measure

The predominant measurement system in use which consists of units such as inches, pounds, gallons, etc.

Metric System

The international system of units as established by the General Conference of Weight and Measures in 1970, and identified as SI (for Systeme International d'Unites).

Time Per Answer

Total time, in minutes, actually used to read and solve problems divided by the number of questions.

Time Per Correct Answer

Total time, in minutes, actually used to read and solve problems divided by only the number of questions answered correctly.

Limitation of the Study

This study was performed only for the industrial employer of the students without intent for application to other employers, training programs, or courses.

Basic Assumption

Time used for each problem, as recorded by the students, is correct.

Procedure for Collecting Data

Twenty students enrolled in an industrial adult training class were given two unannounced timed quizzes. Prior to the first quiz, each student had received instruction, solved problems, and been tested in practical mathematical calculations involving both customary and metric units of measure. Each quiz, with an instruction sheet,

as shown in Appendixes A and B, was validated prior to use, as shown in Appendix C. Half of quiz one used metric units and the other half used customary units. The order was reversed for the second quiz to compensate for any practice effect. The problems were similar to previous course problems and calculators were used for both quizzes. The nature of the problems on each quiz covered linear measurements, area, volume, mass (weight), temperature, force, torque, pressure, power, and work. Ten questions were on each quiz, and the individual start and stop time for each problem was recorded by each student using a large wall clock. Each quiz was given at separate times, one week apart, without advance notice, and included material for which the students had already received instructions and had worked similar problems.

After the raw data were collected, time was converted from minutes and seconds to minutes in decimal form for ease of calculation. Questions missed, as shown in Appendixes D and E, and the frequency of each question missed, by type of problem, as shown in Appendix F, were recorded to determine the number of questions missed and to provide data for any residual finding. Time required to solve each problem was recorded, by units of measure used, as shown in Appendixes G and H, and the average time, by type of problem, as shown in Appendix I, was recorded to determine the time needed to solve problems and to provide data for any residual finding.

Procedure for Treating Data

The bivariate objective of this study was the comparison of time per correct answer for practical mathematical calculations using customary and metric units of measure. The independent variable was the problems worked by adult students, involving the use of customary and metric units of measure, with the dependent variable being the time per correct answer. The null hypothesis was tested using a dependent two-tailed t-test at the .05 level of significance. The dependent t-test was utilized since the same population worked problems in both customary and metric units of measure.

The null hypothesis is designated as H_o and the corresponding research hypothesis is designated as H_{a_1}, and the alternate hypothesis as H_{a_2} where $\overline{X}_c$ = time per correct answer using customary units of measure and $\overline{X}_m$ = time per correct answer using metric units of measure.

The null hypothesis is as follows:

H_o: There is no significant difference in time per correct answer for customary and metric units of measure ($\overline{X}_c - \overline{X}_m = 0$).

The corresponding research hypothesis is as follows:

H_{a_1}: Time per correct answer for customary units of measure is significantly lower than time per correct answer for metric units of measure ($\overline{X}_c < \overline{X}_m$).

The corresponding alternate hypothesis is as follows:

H_{a_2}: Time per correct answer for customary units of measure is significantly higher than time per correct answer for metric units of measure ($\overline{X}_c > \overline{X}_m$).

Depending on the results, the above null hypothesis was to be rejected or accepted based upon a .05 level of significance, utilizing the dependent, two-tailed t-test.

The standard deviation for correct time per answer was determined for comparison of customary and metric units of measure, as shown in Appendixes J and K, respectively. In addition, the dependent two-tailed t-test at a .05 level of significance was performed for both the time per answer, Appendix L, and the time per correct answer, Appendix M, for futher analysis and comparison.

The results of the frequency of problems missed by type and units of measure, Appendix F, and the average time to solve problems by type and units of measure were assessed for trends. Conclusions from the data were used to support residual findings and recommendation.

Chapter 4

DATA RESULTING FROM THE STUDY

The data obtained and calculations performed are contained in Appendixes D through M for the purposes of future reference and comparison of replicated studies. Analysis of these data revealed that all students made a grade of 70 or higher for both customary and metric quizzes, as shown in Appendixes D and E. The total number of problems missed using customary units of measure were thirty-one and fourteen problems missed using metric units of measure, as shown in Appendix F. Thus, the mean grade of 84.5 for customary units of measure was increased by 10.1 percent to 93.0 for metric units of measure. The total test time for all students was reduced from 329.27 minutes for customary units of measure to 195.92 minutes for metric units of measure, as shown in Appendixes C and H, for mean test times of 16.46 and 9.80 respectively. Thus, the time for customary units of measure was reduced 40.5 percent for metric units of measure, as shown in Appendix I. Further analysis of the initial data revealed the time per correct answer for customary units of measure was 2.0 minutes with a standard deviation of .80 and 1.1 minutes for metric units of measure with a standard deviation of .43, as shown in Appendixes J and K.

The null hypothesis for time per correct answer was evaluated at the .05 level of significance utilizing the dependent two-tailed t-test. With $t_{.05}$ = 2.093 for nineteen degrees of freedom (Isaac, 1981:178), the calculated t value was 6.618, as shown in Appendix M.

The above test of significance was used to evaluate total test time by units of measure. With $t_{.05}$ = 2.093, the calculated t value was 6.292, as shown in Appendix L. In addition, the same test of significance was performed on the number of correct answers for customary and metric units of measure. With $t_{.05}$ = 2.093, the calculated t value was 4.337, as shown in Appendix N.

A further review of other data resulting from this study, as shown in Appendix F, revealed the most frequent types of customary problems missed were temperature, area (of a triangle), and linear measurement. The most frequent types of metric problems missed were temperature and pressure. A comparison of mean time to solve problems, by type, as shown in Appendix I, revealed less time was spent on metric problems except for torque where the mean time was .04 minutes greater for metric units of measure.

Chapter 5

CONCLUSION AND SIGNIFICANCE

Since the calculated value of t(6. 618) exceeds the critical t value (2. 093), the null hypothesis for time per correct answer is rejected. There is a significant difference between the time per correct answer to perform practical mathematical calculations in customary and metric units of measure. Thus, the alternate hypothesis (H_{a_2}) is accepted which reveals the time per correct answer for customary units of measure is significantly higher than time per correct answer for metric units of measure. The value of t(6. 292) for test time by units of measure also exceeds the critical t value, therefore, both time per correct answer and test time reveal significantly less time was required to solve practical mathematical calculations using metric units of measure. In addition, the value of t (4. 339) for number of correct answers exceeds the critical t value, therefore, the number of correct metric questions is significantly higher than the number of correct customary questions.

It is concluded that time per correct answer and test time were significantly less and that significantly more problems were answered correctly using metric units of measure.

Residual Findings

The aspect of the frequency of problems missed, by type, required further investigation. While a review of the calculations performed revealed some calculation errors, insufficient information was available. The results of the quizzes were reviewed with the students and each student was offered the opportunity to comment on any aspect of the design and conduct of the quizzes and any problems answered incorrectly. Their comments included lack of previous announcement, thus they did not prepare in advance for the quizzes. More specifically, the comments predominantly indicated that customary problems for linear measurement were missed due to not closely observing the feet and inches symbols. Incorrect customary area calculations were due to use of mixed fractions and incorrectly calculating a conversion factor for square yards. The reason given for the pressure problem in metric units was lack of familiarity with the units newton and pascal due to infrequent use. The main reason given for missing the temperature question for both customary and metric units was that it was a "thought question" and missed due to failure to clearly think about the question. However, the reason given for customary temperature being missed more frequently than metric temperature was failure to calculate the freezing point at 32 degrees Fahrenheit as compared to zero degrees Celsius for the metric system.

In addition, the students were asked to comment on why the metric torque question took a longer period of time. Their response was that the slight time difference of .04 minutes was due to lack of familiarity with the unit newton due to infrequent use, which was also the reason given for the metric pressure question.

Thus, the residual findings were that certain aspects of the present training course need more emphasis. Customary length symbols, calculations of customary conversion factors, customary temperature scale, and infrequent use of the metric units newton and pascal were identified weaknesses in the present course of instruction.

During the conduct of this study an invitation was received to present the results to the 1986 U. S. Metric Association's Annual Conference to be held at the Marshal Space Flight Center, Huntsville, Alabama. In addition, as a result of the validation process for the quizzes, a request has been received to make the quizzes and statistical process available at the conference. This would enable college instructors who are members of the U. S. Metric Association to give the quizzes and report the results to the association for the purpose of increasing the data base and comparing different parts of the country as well as different types of students.

Recommendations

The purpose of this study set forth the objective to determine if industrial adult students engaged in training for high technology jobs can realize a time saving if only customary or metric units of measure are used. The results have been reviewed and a recommendation made for industrial training to move toward the use of only metric units of measure for training, to the extent permitted by limiting factors Such factors include measuring and test equipment, specifications, blueprints and related documents, to be used in future job assignments, which are not in metric units of measure. The recommendation was approved.

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APPENDIX A

QUIZ ONE

Name: _____

Date: _____

QUIZ INSTRUCTIONS

Do not turn this page until you read and clearly understand the following instructions. Before starting the quiz, please ask any questions you may have if the instructions are not clearly understood.

The following quiz consists of ten problems involving practical mathematical calculations. Before reading each question, record the start time in the space marked START TIME. Proceed to work the problem, using the space provided, and record your answer with the appropriate unit of measure in the space marked ANSWER. Record the stop time in the space marked STOP TIME and proceed to the next question, repeating the above instructions. All time entries are to be recorded as minutes and seconds (for example, 20:37) using the large clock at the front of the room. Calculators may be used.

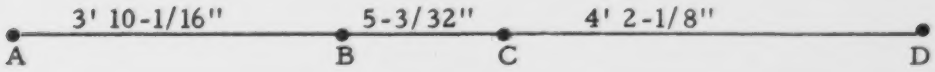
Concentrate on obtaining the correct answer rather than on time. Answers do not have to be recorded to more than three decimal places using rounding off rules when applicable.

APPENDIX A (Cont.)

QUIZ ONE

1. START TIME: ____ : ____

What is the total distance between point A and point D in inches?

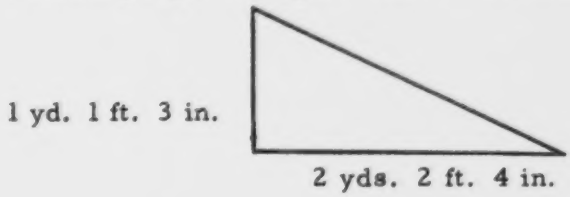


(Sketch not to scale)

ANSWER: _____
STOP TIME: ____ : ____

2. START TIME: ____ : ____

Given the following right triangle, what is its area in square yards?

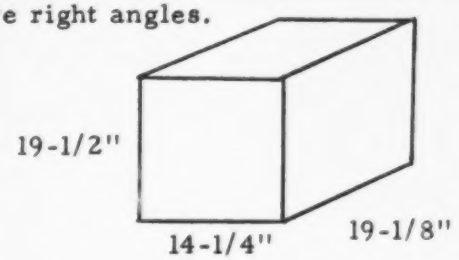


(Sketch not to scale)

ANSWER: _____
STOP TIME: ____ : ____

3. START TIME: ____ : ____

What is the volume of the container shown below in cubic yards? All angles are right angles.



(Sketch not to scale)

ANSWER: _____
STOP TIME: ____ : ____

4. START TIME: ____ : ____

What is the sum of the following in pounds?

3 lbs 5 oz
5 lbs 9 oz
6 oz
1/4 oz

ANSWER: _____
STOP TIME: ____ : ____

APPENDIX A (Cont.)

5. START TIME: _____ : _____

If a material is to be treated by raising its temperature from freezing to 50°F above the boiling point of water and then lowered 185°F, what is the difference from its starting and final temperature?

ANSWER: _____
STOP TIME: _____ : _____

6. START TIME: _____ : _____

Given a mass *(m)* of 4.5 kg and an acceleration (a) of 2.4 m/s^2, find the resulting force *(F)* in newtons.

ANSWER: _____
STOP TIME: _____ : _____

7. START TIME: _____ : _____

A lever arm 1.7 meters in length produces a torque of 1.615 newton meters. How much force is applied to the lever arm?

ANSWER: _____
STOP TIME: _____ : _____

APPENDIX A (Cont.)

8. START TIME: _____

A force of 1800 newtons produces a pressure of 998 pascals. What is the size of the area to which this force is applied?

ANSWER: _____
STOP TIME: _____ : _____

9. START TIME: _____ : _____

Given a force of 5 newtons applied for a distance of 1.5 meters, determine the amount of work performed in joules.

ANSWER: _____
STOP TIME: _____ : _____

10. START TIME: _____ : _____

How many watts of power are needed for a machine to apply a force of 590 newtons for a distance of 100 meters during a time period of 8 seconds?

ANSWER: _____
STOP TIME: _____ : _____

APPENDIX B

QUIZ TWO

Name: _____

Date: _____

QUIZ INSTRUCTIONS

Do not turn this page until you read and clearly understand the following instructions. Before starting the quiz, please ask any questions you may have if the instructions are not clearly understood.

The following quiz consists of ten problems involving practical mathematical calculations. Before reading each question, record the start time in the space marked START TIME. Proceed to work the problem, using the space provided, and record your answer with the appropriate unit of measure in the space marked ANSWER. Record the stop time in the space marked STOP TIME and proceed to the next question, repeating the above instructions. All time entries are to be recorded as minutes and seconds (for example, 20:37) using the large clock at the front of the room. Calculators may be used.

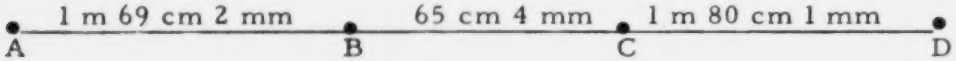
Concentrate on obtaining the correct answer rather than on time. Answers do not have to be recorded to more than three decimal places using rounding off rules when applicable.

APPENDIX B (Cont.)

QUIZ TWO

1. START TIME: ____ : ____

What is the total distance between point A and point D in centimeters?

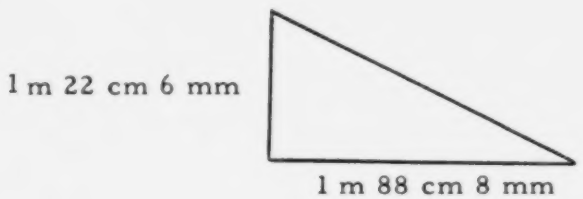


(Sketch not to scale)

ANSWER: _____
STOP TIME: ____ : ____

2. START TIME: ____ : ____

Given the following right triangle, what is its area in square meters?

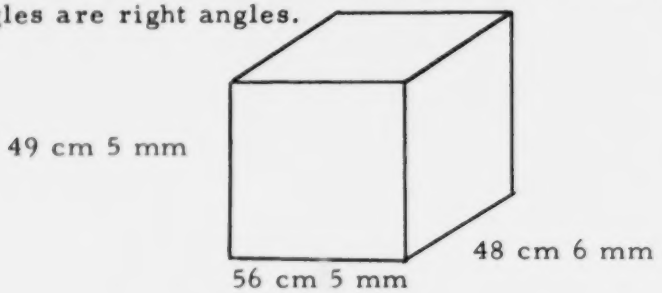


(Sketch not to scale)

ANSWER: _____
STOP TIME: ____ : ____

3. START TIME: _____ : _____

What is the volume of the container shown below in cubic meters? All angles are right angles.



ANSWER: _____
STOP TIME: _____ : _____

4. START TIME: _____

What is the sum of the following masses in kilograms?

1 kg 501 g
2 kg 523 g
170 g
7 g

ANSWER: _____
STOP TIME: _____ : _____

APPENDIX B (Cont.)

5. START TIME: ____ : ____

If a material is to be tested by raising its temperature from freezing to 10°C above the boiling point of water and then lowered 85°C, what is the difference from its starting and final temperature?

ANSWER: _____
STOP TIME: ____ : ____

6. START TIME: ____ : ____

Given a weight (W) of 10 pounds, pull of gravity (g) at 32 ft./sec^2 and an acceleration (a) of 8 ft./sec^2, find the resulting force (F) in pounds.

ANSWER: _____
STOP TIME: ____ : ____

7. START TIME: ____ : ____

A force of 2.1 pounds produces a torque of 11.55 foot pounds. What is the length of the lever arm?

ANSWER: _____
STOP TIME: ____ : ____

8. START TIME: _____ : _____

A force of 513 pounds produces a pressure of 27 pounds per square foot. What is the size of the area to which this force is applied?

ANSWER: _____
STOP TIME: _____ : _____

9. START TIME: _____ : _____

A box pushed 3 feet along a horizontal floor requires 5.4 foot pounds of work. What is the force on the floor?

ANSWER: _____
STOP TIME: _____ : _____

10. START TIME: _____ : _____

A man who weighs 220 pounds can run 100 feet in 4.0 seconds. What is his power output in horsepower? (1.0 hp = 550 ft. lbs/sec)

ANSWER: _____
STOP TIME: _____ : _____

APPENDIX C

VALIDATION OF QUIZZES

The quizzes contained in Appendixes A and B were validated by a physics instructor, three graduate engineers, a dimensional metrology and mathematics instructor, and an industrial manager of a metrology laboratory. In addition, further validation was performed by the President of the U. S. Metric Association, Valerie Antonie, and George Stoner, a retired science professor. The validation effort included an evaluation of metric versus customary problems for equal complexity, amount of calculations involved, reasonableness of questions, correct usage of units of measure, biasness toward either measurement system, completeness of instructions, and typographical errors. The validation effort resulted in a few minor changes for correct usage of units of measure.

The most significant inputs from the validation effort were received from Antoine and Stoner and are quoted below. The letter from Stoner, forwarded by Antoine, was received after the quizzes were given. However, the 65 percent (35 percent weighted average) reduction in time to solve problems in the metric system served as an optimum benchmark for comparing the results of the data.

APPENDIX C (Continued)

Quoted Letters

Valerie Antoine
10245 Andasol Ave.
Northridge, CA 91325

30 Mar 85

E. James Tew, Jr.
10235 Mapleridge Dr.
Dallas, TX 75238

Dear Jim:

Your quizzes seem well balanced and I believe give the problems pretty well evenly insofar as I-P and SI [customary and metric units] are concerned. I am sending a copy to George Stoner and asked him to do a test on the two quizzes and send the time for each problem to me (and I'll forward it to you when he sends it).

Found a few typos in your copies so marked up the quizzes you sent me and am returning them with my comments. Also will furnish some italicized copy on avery, for you to cover those items on your master, in case your typewriter doesn't have the capability to type italics where they are needed.

Looking forward to getting your test results.

Valerie Antonie

APPENDIX C (Continued)

George Stoner, Ph. D.
2 Parkside Dr.
Suffern, NY 10901

Sat., 4 May 1985

Valerie Antoine, CAMS, President
U. S. Metric Association, Inc.
10245 Andasol Avenue
Northridge, CA 91325

Dear Valerie,

Enclosed is a typed copy of "MY RESULTS ON THE TWO QUIZZES DRAFTED BY JAMES TEW FOR ENGINEERS" that you requested in your letter of 30 Mar 85. Certainly for me, SI [metric units] enabled me to solve the problems faster. The 1st column below shows my I-P [customary units] time in seconds, the 2nd column shows my SI time in seconds, the 3rd column shows how many seconds faster the SI time was, and the 4th column shows the SI time as a percentage of I-P time.

I-P time	SI time	SI time advantage	SI time as a percentage of I-P time	Problem #
75 s	47 s	28 s	63%	1
136	52	84	38%	2
92	63	29	68%	3
200	57	143	29%	4
92	31	61	34%	5
307	25	282	8%	6
38	32	6	84%	7
112	40	72	36%	8
69	10	59	14%	9
104	70	34	67%	10
Total 1225 s	427 s	798 s	Weighted av. = 35%, i. e., 427 s is 35% of 1225 s.	

APPENDIX C (Continued)

James Tew deserves much credit and our thanks for working out such a carefully designed test. His presentation of the results ought to make a dramatic presentation at the Huntsville conference in October, 1985.

George Stoner

NOTE: All problems were answered correctly.

APPENDIX D

PROBLEMS MISSED USING CUSTOMARY UNITS OF MEASURE

Student	Quiz One Problems					Quiz Two Problems					Total
	1	2	3	4	5	6	7	8	9	10	
1					X						1
2											0
3				X							1
4					X			X			2
5											0
6		X			X					X	3
7		X			X						2
8	X	X								X	3
9	X	X			X						3
10		X			X						2
11	X				X						2
12		X	X								2

APPENDIX D (Continued)

Student	Quiz One Problems					Quiz Two Problems					Total
	1	2	3	4	5	6	7	8	9	10	
13										X	1
14											0
15	X				X					X	3
16		X									1
17								X			1
18		X									1
19					X						1
20	X							X			2
Totals	5	8	1	1	9	0	0	3	0	4	31

APPENDIX E

PROBLEMS MISSED USING METRIC UNITS OF MEASURE

Student	Quiz Two Problems					Quiz One Problems					Total
	1	2	3	4	5	6	7	8	9	10	
1											0
2											0
3			X								1
4											0
5											0
6								X			1
7					X			X			2
8											0
9	X	X					X				3
10											0
11					X						1
12					X						1

APPENDIX E (Continued)

Student	Quiz Two Problems					Quiz One Problems					Total
	1	2	3	4	5	6	7	8	9	10	
13											0
14											0
15					X			X			2
16											0
17								X			1
18								X			1
19					X						1
20											0
Totals	1	1	1	0	5	0	1	5	0	0	14

APPENDIX F

FREQUENCY OF PROBLEMS MISSED
BY TYPE AND UNITS OF MEASURE

Type of Problem	Frequency		Total
	Customary	Metric	
Linear Measurement	5	1	6
Area (Triangle)	8	1	9
Volume	1	1	2
Mass (Weight)	1	0	1
Temperature	9	5	14
Force	0	0	0
Torque	0	1	1
Pressure	3	5	8
Work	0	0	0
Power	4	0	4
Total	31	14	45

Average Grade for Customary Units of Measure:	84.50
Average Grade for Metric Units of Measure:	93.00
Average Grade Increase from Customary to Metric Units of Measure	10.06%

APPENDIX G

TIME TO SOLVE PROBLEMS USING
CUSTOMARY UNITS OF MEASURE

Student	Time in Minutes for Each Problem										Total
	1	2	3	4	5	6	7	8	9	10	
1	1.50	1.17	0.83	2.50	0.58	1.08	0.83	0.67	0.75	1.17	11.08
2	1.75	4.15	1.28	1.48	0.68	0.68	0.43	0.53	0.50	0.50	11.98
3	2.50	2.00	3.00	2.00	2.42	2.00	3.00	1.00	1.00	1.00	19.92
4	1.42	1.83	2.28	1.42	0.98	1.67	0.78	1.03	1.23	0.88	13.42
5	2.33	3.25	1.83	1.00	2.67	1.58	1.17	1.42	1.83	1.92	19.00
6	4.00	6.00	3.50	3.00	3.00	1.00	1.00	1.00	1.00	1.00	24.50
7	5.20	2.25	3.50	1.00	1.75	1.50	2.00	2.00	0.83	1.08	21.11
8	0.73	2.43	2.33	1.08	1.80	0.67	0.92	1.50	0.75	1.92	14.13
9	1.60	2.28	1.83	0.62	1.47	1.92	1.15	6.25	1.03	1.52	19.67
10	1.00	7.00	3.00	3.00	2.00	0.92	0.75	1.25	0.83	0.67	20.42
11	0.83	1.00	1.75	1.92	0.33	1.43	0.58	0.67	0.50	1.17	10.18

43

APPENDIX G (Continued)

Student	Time in Minutes for Each Problem										Total
	1	2	3	4	5	6	7	8	9	10	
12	2.50	8.25	5.67	0.75	0.42	2.67	1.00	1.00	1.00	1.17	24.43
13	0.92	1.25	0.50	0.42	0.42	0.50	0.58	0.58	0.58	3.67	9.42
14	1.50	1.75	2.17	1.17	0.50	0.50	0.67	0.50	0.42	0.50	9.68
15	1.00	3.00	3.00	1.00	1.00	0.50	1.00	4.00	1.00	5.00	20.50
16	4.25	4.08	6.08	3.50	3.50	1.50	1.08	0.92	1.25	1.67	27.83
17	3.00	2.00	2.50	2.00	1.00	1.00	1.00	1.00	1.00	2.00	16.50
18	5.33	1.50	2.00	1.08	0.67	1.25	0.50	2.25	0.33	0.50	15.41
19	0.73	0.67	0.50	0.62	0.45	0.60	0.40	0.35	0.30	0.63	5.25
20	2.43	2.72	3.42	0.67	1.00	1.55	0.78	0.42	0.52	1.33	14.84
Total	44.52	58.48	50.97	30.23	26.64	24.52	19.62	28.34	16.65	29.30	329.27
$\overline{X}$	2.23	2.92	2.55	1.51	1.33	1.23	.98	1.42	.83	1.46	16.46

APPENDIX H

TIME TO SOLVE PROBLEMS USING METRIC UNITS OF MEASURE

Student	Time in Minutes for Each Problem										Total
	1	2	3	4	5	6	7	8	9	10	
1	0.67	0.33	0.50	0.58	0.42	0.42	0.58	0.58	0.50	0.58	5.16
2	0.62	0.52	0.72	0.62	0.38	0.70	1.15	1.85	0.48	0.87	7.91
3	2.00	2.00	2.00	2.00	1.00	1.00	2.00	1.00	1.00	1.00	15.00
4	0.80	0.67	0.75	0.73	0.50	1.38	1.40	1.23	0.58	0.78	8.82
5	1.08	0.92	1.83	0.67	0.63	0.83	1.50	1.63	1.67	1.33	12.09
6	1.00	2.00	1.00	1.00	1.00	1.00	1.00	3.00	2.00	1.00	14.00
7	0.42	0.50	0.50	0.50	0.50	1.50	0.92	1.50	0.92	1.25	8.51
8	1.00	0.42	1.50	0.67	0.50	3.08	1.32	2.07	0.62	0.72	11.90
9	1.68	1.58	1.43	1.03	0.85	1.05	1.35	2.00	1.32	1.08	13.37
10	1.00	0.97	0.90	1.05	1.00	4.00	1.00	2.00	1.00	1.00	13.92
11	0.87	0.75	0.50	0.48	0.92	0.67	0.75	1.33	0.25	0.58	7.10
12	0.67	0.92	0.75	0.58	0.67	0.75	1.33	1.50	0.67	1.00	8.84

APPENDIX H (Continued)

Student	Time in Minutes for Each Problem										Total
	1	2	3	4	5	6	7	8	9	10	
13	0.42	0.50	0.42	0.33	0.42	0.33	0.42	0.67	0.75	0.50	4.76
14	0.33	0.50	0.42	0.25	0.42	0.33	0.50	0.92	0.37	0.58	4.62
15	2.00	2.00	2.25	1.00	2.00	1.00	0.75	1.00	0.50	1.00	13.50
16	1.25	0.42	0.83	0.58	1.67	0.83	1.08	2.17	0.67	1.33	10.83
17	2.00	1.00	1.50	1.00	1.00	2.00	1.00	1.00	0.50	1.00	12.00
18	0.50	1.50	1.00	0.50	0.42	0.75	0.50	0.50	0.33	0.75	6.75
19	0.67	0.45	0.68	0.42	0.37	0.43	1.02	1.68	0.63	3.48	9.83
20	0.40	1.25	0.55	0.52	0.67	0.57	0.90	0.87	0.63	0.65	7.01
Total	19.38	19.20	20.03	14.51	15.34	22.62	20.47	28.50	15.39	20.48	195.92
$\overline{X}$	.97	.96	1.00	.73	.77	1.13	1.02	1.43	.77	1.02	9.80

APPENDIX I

AVERAGE TIME TO SOLVE PROBLEMS
BY TYPE AND UNITS OF MEASURE

Type of Problem	Time in Minutes	
	Customary	Metric
Linear Measurement	2.23	.97
Area (Triangle)	2.92	.96
Volume	2.55	1.00
Mass (Weight)	1.51	.73
Temperature	1.33	.77
Force	1.23	1.13
Torque	.98	1.02
Pressure	1.42	1.43
Work	.83	.77
Power	1.46	1.02
Total	16.46	9.80

APPENDIX J

STANDARD DEVIATION CALCULATIONS FOR TIME PER CORRECT ANSWER USING CUSTOMARY UNITS OF MEASURE

Student	Total Test Time in Minutes	Number Correct Answers	Time Per Correct Answer in Minutes (X)	X^2
1	11.08	9	1.231	1.515
2	11.98	10	1.198	1.435
3	19.92	9	2.213	4.897
4	13.42	8	1.678	2.816
5	19.00	10	1.900	3.610
6	24.50	7	3.500	12.250
7	21.11	8	2.639	6.964
8	14.13	7	2.019	4.076
9	19.67	7	2.810	7.896
10	20.42	8	2.552	6.513
11	10.18	8	1.272	1.618
12	24.43	8	3.054	9.327
13	9.42	9	1.047	1.096
14	9.68	10	.968	.937
15	20.50	7	2.929	8.579
16	27.83	9	3.092	9.560

APPENDIX J (Continued)

Student	Total Test Time in Minutes	Number Correct Answers	Time Per Correct Answer in Minutes (X)	X^2
17	16.50	9	1.833	3.360
18	15.41	9	1.712	2.931
19	5.25	9	.583	0.340
20	14.84	8	1.855	3.441
Totals	329.27	169		
ΣX			40.085	
ΣX^2				93.161
Mean	16.46	8.45	2.004	

$$S_c = \sqrt{\frac{n(\Sigma X^2) - (\Sigma X)^2}{n^2}}$$

$$S_c = \sqrt{\frac{20(93.161) - (40.085)^2}{20^2}}$$

$$S_c = \sqrt{\frac{1863.22 - 1606.81}{400}}$$

$$S_c = .80$$

APPENDIX K

STANDARD DEVIATION CALCULATIONS FOR TIME PER CORRECT ANSWER USING METRIC UNITS OF MEASURE

Student	Total Test Time in Minutes	Number Correct Answers	Time Per Correct Answer in Minutes (X)	X^2
1	5.16	10	.516	.266
2	7.91	10	.791	.626
3	15.00	9	1.667	2.779
4	8.82	10	.882	.778
5	12.09	10	1.209	1.462
6	14.00	9	1.556	2.421
7	8.51	8	1.604	2.573
8	11.90	10	1.190	1.416
9	13.37	7	1.910	3.648
10	13.92	10	1.392	1.938
11	7.10	9	.789	.623
12	8.84	9	.982	.964
13	4.76	10	.476	.227
14	4.62	10	.462	.213
15	13.50	8	1.688	2.849
16	10.83	10	1.083	1.173

APPENDIX K (Continued)

Student	Total Test Time in Minutes	Number Correct Answers	Time Per Correct Answer in Minutes (X)	X^2
17	12.00	9	1.333	1.777
18	6.75	9	.750	.562
19	9.83	9	1.092	1.192
20	7.01	10	.701	.491
Totals	195.92	186		
ΣX			22.073	
ΣX^2				27.978
Mean	9.80	9.30	1.104	

$$S_m = \sqrt{\frac{n(\Sigma X^2) - (\Sigma X)^2}{n^2}}$$

$$S_m = \sqrt{\frac{20(27.978) - (22.073)^2}{20^2}}$$

$$S_m = \sqrt{\frac{559.56 - 487.22}{400}}$$

$$S_m = .43$$

APPENDIX L

DEPENDENT TWO-TAILED t-TEST CALCULATIONS FOR TOTAL TEST TIME USING CUSTOMARY AND METRIC UNITS OF MEASURE

Student	Time in Minutes		D	D^2
	T_c	T_m		
1	11.08	5.16	5.92	35.05
2	11.98	7.91	4.07	16.56
3	19.92	15.00	4.92	24.21
4	13.42	8.82	4.60	21.16
5	19.00	12.09	6.91	47.75
6	24.50	14.00	10.50	110.25
7	21.11	8.51	12.60	158.76
8	14.13	11.90	2.23	4.73
9	19.67	13.37	6.30	39.69
10	20.42	13.92	6.50	42.25
11	10.18	7.10	3.08	9.49
12	24.43	8.84	15.59	243.05
13	9.42	4.76	4.66	21.72
14	9.68	4.62	5.06	25.60
15	20.50	13.50	7.00	49.00
16	27.83	10.83	17.00	289.00

APPENDIX L (Continued)

Student	Time in Minutes T_c	Time in Minutes T_m	D	D^2
17	16.50	12.00	4.50	20.25
18	15.41	6.75	8.66	75.00
19	5.25	9.83	-4.58	20.98
20	14.84	7.01	7.83	61.31
Totals	329.27	195.92		
ΣD			133.35	
ΣD^2				1315.81
Mean	16.46	9.80	6.67	

$$\Sigma d^2 = \Sigma D^2 - \frac{(\Sigma D)^2}{n}$$

$$\Sigma d^2 = 1315.81 - \frac{(133.35)^2}{20}$$

$$\Sigma d^2 = 1315.81 - 889.11$$

$$\Sigma d^2 = 426.70$$

$$df = n - 1 = 20 - 1 = 19$$

$\alpha = .05$, dependent two-tailed t-test

$t_{.05} = 2.093$

APPENDIX L (Continued)

$$t = \frac{\bar{D}}{\sqrt{\frac{\Sigma d^2}{n(n-1)}}}$$

$$t = \frac{6.670}{\sqrt{\frac{426.70}{(20)(19)}}}$$

$$t = \frac{6.670}{1.060}$$

$$t = 6.292$$

$$6.292 > 2.093$$

APPENDIX M

DEPENDENT TWO-TAILED t-TEST CALCULATIONS FOR TIME PER CORRECT ANSWER USING CUSTOMARY AND METRIC UNITS OF MEASURE

Student	Time in Minutes		D	D^2
	T_c	T_m		
1	1.231	.516	.715	.511
2	1.198	.791	.407	.166
3	2.213	1.667	.546	.298
4	1.678	.882	.796	.634
5	1.900	1.209	.691	.477
6	3.500	1.556	1.944	3.779
7	2.639	1.604	1.035	1.071
8	2.019	1.190	.829	.687
9	2.810	1.910	.900	.810
10	2.552	1.392	1.160	1.346
11	1.272	.789	.483	.233
12	3.054	.982	2.072	4.293
13	1.047	.476	.571	.326
14	.968	.462	.506	.256
15	2.929	1.688	1.241	1.540
16	3.092	1.083	2.009	4.036

APPENDIX M (Continued)

Student	Time in Minutes		D	D^2
	T_c	T_m		
17	1.833	1.333	.500	.250
18	1.712	.750	.962	.925
19	.583	1.092	-.509	.259
20	1.855	.701	1.154	1.332
Totals	40.085	22.073		
ΣD			18.012	
ΣD^2				23.229
Mean	2.004	1.104	.900	

$$\Sigma d^2 = \Sigma D^2 - \frac{(\Sigma D)^2}{n}$$

$$\Sigma d^2 = 23.229 - \frac{(18.012)^2}{20}$$

$$\Sigma d^2 = 23.229 - 16.222$$

$$\Sigma d^2 = 7.007$$

$$df = n - 1 = 20 - 1 = 19$$

α = .05, dependent two-tailed t-test

$t_{.05} = 2.093$

APPENDIX M (Continued)

$$t = \frac{\bar{D}}{\sqrt{\frac{\Sigma d^2}{n(n-1)}}}$$

$$t = \frac{.900}{\sqrt{\frac{7.007}{(20)(19)}}}$$

$$t = \frac{.900}{.136}$$

$$t = 6.618$$

$$6.618 > 2.093$$

APPENDIX N

DEPENDENT TWO-TAILED t-TEST CALCULATIONS
FOR CORRECT ANSWERS USING CUSTOMARY
AND METRIC UNITS OF MEASURE

Student	Number Correct Answers		D	D^2
	Metric	Customary		
1	10	9	1	1
2	10	10	0	0
3	9	9	0	0
4	10	8	2	4
5	10	10	0	0
6	9	7	2	4
7	8	8	0	0
8	10	7	3	9
9	7	7	0	0
10	10	8	2	4
11	9	8	1	1
12	9	8	1	1
13	10	9	1	1
14	10	10	0	0
15	8	7	1	1
16	10	9	1	1

APPENDIX N (Continued)

Student	Number Correct Answers		D	D^2
	Metric	Customary		
17	9	9	0	0
18	9	9	0	0
19	9	9	0	0
20	10	8	2	2
Totals	186	169		
ΣD			17	
ΣD^2				29
Mean	9.30	8.45	.85	

$$\Sigma d^2 = \Sigma D^2 - \frac{(\Sigma D)^2}{n}$$

$$\Sigma d^2 = 29 - \frac{(17)^2}{20}$$

$$\Sigma d^2 = 29 - 14.45$$

$$\Sigma d^2 = 14.55$$

$$df = n - 1 = 20 - 1 = 19$$

α = .05, dependent two-tailed t-test

$t_{.05} = 2.093$

APPENDIX N (Continued)

$$t = \frac{\bar{D}}{\sqrt{\frac{\Sigma d^2}{n(n-1)}}}$$

$$t = \frac{.850}{\sqrt{\frac{14.55}{(20)(19)}}}$$

$$t = \frac{.850}{.196}$$

$$t = 4.337$$

$4.337 > 2.093$